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# Performance of a nitrogen laser with a modified electrode configuration and gas flow arrangement

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**Abstract.** A compact nitrogen laser with brass anode and hacksaw blade cathode has been constructed The nitrogen flow is across the electrodes The blumlein line is formed by copper and aluminium sheets with polyster as a dielectric. The output power as function of pressure, voltage and flow rate has been measured. The laser generates sufficient power to pump some dyes to amplified spontaneous emission. The focussed beam produces sparks on copper plate and also triggers spark gaps.

## 1. Introduction

Since the discovery of laser action from nitrogen in the ultraviolet (Heard 1963), the nitrogen laser has enjoyed a great popularity because of its non-critical construction, use of readily available inexpensive gas and room-temperature operation. $N_2$ laser is also an efficient dye laser pump, and a promosing candidate in the area of laser isotope separation.

Lasing action occurs on some 30 different rotational transitions of the (0, 0) band of $C^3\pi_u - B^3\pi_g$ system (Parks *et al* 1968), and the principal output is an envelope of spectral lines centered at 3371 Å and less than 1 Å wide.

The mechanism of laser action is peculiar as the spontaneous radiative lifetime of the upper $C^3\pi_u$ level is about 40 nsec, much shorter than that of the lower $B^3\pi_g$ level, which is about 6 $\mu$sec. Therefore, high proportion of stimulated emission can be achieved only if the population inversion is achieved in a time shorter than the life time of $C^3\pi_u$ state. The condition of fast population inversion can be achieved by a low impedence Blumlein pulse generator in the form of a parallel plate transmission line (Shipman 1967). Also, the electron excitation cross-section of the $C^3\pi_u$ state is 1·6 times the cross-section of the $B^3\pi_g$ state (Cartweight 1970) and this contribu es owards efficien popula ion inversion. A steady progress on fast discharge $N_2$ laser has been made through the work of Geller *et al* (1968), Basting *et al* (1972), Small *et al* (1972), Godard (1974), Levatter *et al* (1974), Wang (1976) and others. This paper describes a Blumlein discharge $N_2$ laser with modified electrode structure and gas flow arrangement and reports on its performance.

## 2. Description of the laser device

The Blumlein line is formed by sandwiching polyster sheets between copper sheets and an aluminium plate. The copper sheets terminate in the laser electrodes. The laser channel is made by two rectangular brass rods (12 cms × 1·9 cm) covered with 1·2 cm thick plexiglass plates at the top and the bottom. The cathode structure consists of hacksaw blades placed 3 thick and 90 cms long in a grove cut in one of the brass rods. The sharp teeth of the hacksaw blades provide an intense electric field at the cathode surface to encourage field emission and initiate many electron avalanches over the cathode surface and close packing helps to maintain a homogeneous field distortion which inhibits streamer and subsequent arc formation (Hasson *et al* 1974, Koppitz 1973). The anode is 3 mm thick with rounded tip milled in the other brass rod On the rear side of both bars a grove of 8 mm width and 6 mm deep is cut all along the length of the bars and covered with brass plates to form gas chambers. Holes of 1 mm diameter and spaced 1·5 cm are drilled on either side of the cathode structure and these open into the gas chamber. Similar holes are drilled on either side of the anode but are made larger in diameter in order to reduce resistance to pump out. The gas flows from cathode to anode through these holes. The distance between the cathode and the anode is 9 mm to 10 mm. The cross-section of the laser channel is shown in figure 1. A front surface aluminised plane mirror is fixed

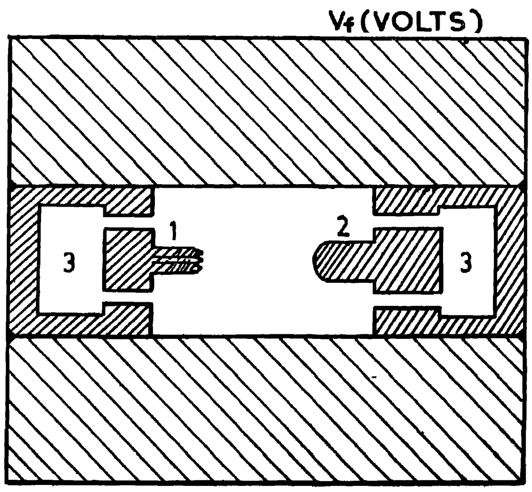


**Figure 1.** Cross-section of the laser channel
1 Cathode, 2 Anode, 3 Gas chamber

at one end of the channel. The mirror can be tilted by the screw attached to the mirror holder. A quartz window is epoxied at the other end of the channel. The gas pressure in the laser channel is measured by the pressure gauge. The gas flow rate is measured by a float type flow meter. The electric power to the Blumlein line is supplied from a high voltage half wave rectifier through a charging resistor. From geometrical considerations the total capacitance of the Blumlein line is estimated to be 0·03 $\mu$F. A non-triggered copper electrode spark gap at atmospheric pressure is used to short circuit one section of the blumlein line.

### 3. Performance of the laser

The E.G. and G power meter (model 460) was used to measure average output power of the laser.

To describe the behaviour of the $N_2$ laser power output as a function of various parameters it is of advantage to assign electron temperature $T_e$, to the nitrogen discharge plasma. It has been shown by Englehardt *et al* (1964) and Klein *et al* (1972) that the electron distribution function for a nitrogen discharge is close to Maxwellian when the ratio of the average electric field to the gas pressure ($E/p$) in the discharge exceeds 30 or 40 volts/cm torr and the $N_2$ lasers efficiently lase at higher ($E/p$) values.

The laser power as a function of nitrogen pressure at a number of different charging voltages is shown in figure 2. It is seen that the optimum laser out

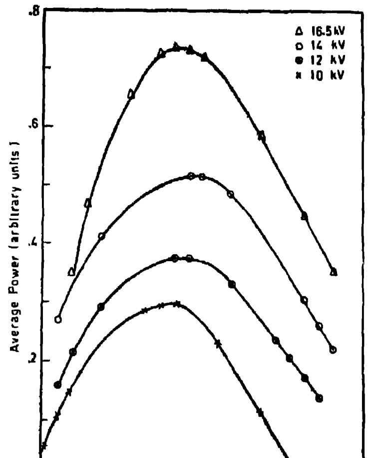


**Figure 2.** Variation of laser power with pressure

put is obtained when the E/$p$ value is in the range of 80 to 130 V/cm torr. The actual E value in the discharge could be more because of the oscillations in the discharge tube leading to slightly higher values for E/$p$. Godard (1974) has tried to estimate the best E/$p$ value for maximum laser efficiency by arguing that the average electric field should accelerate the electrons, within their mean free path at a given pressure, to the value where the total electron excitation cross section has the maximum and derived a theoretical value of E/$p$ = 250 v/cm. torr and experimentally obtained the optimum value for E/$p$ to be 200 v/cm torr. However, it is found that the other $N_2$ laser design where some sort of pre-ionization is induced give much lower optimum E/p value.

The initial increase in the laser power with increasing pressure is due to the fact that the number of molecules available for inversion keeps on increasing as the pressure is increased with electron temperature of the plasma remaining fairly high. The fall in the output power at higher pressures is due to the decrease of $T_e$ and also due to onset of arcing.

The power out put as a function of charging voltage is shown in figure 3. The trend of the power out put towards saturation could be due to non linear dependence of the excitation cross section on $T_e$ which in turn depends on the charging voltage.

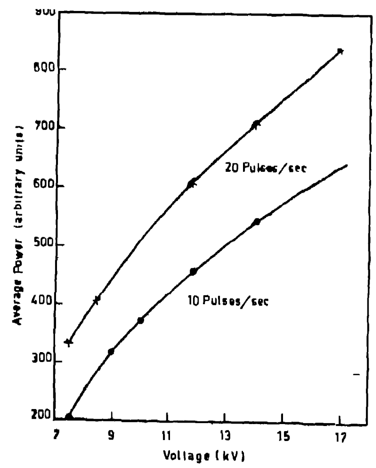


**Figure 3.** Variation of laser power with charging voltage

To study the role of transverse gas flow the dependence of laser power on the pulse repetition at different flow rates was measured. The results are shown in figure 4. The discharge contains ions, dissociated atoms electronically excited molecules and rotationally or vibrationally hot molecules for which electron excitation to appropriate excited states is unlikely. The observed Lewis-Rayleigh afterglow after the main discharge indicates the presence of such spcies. For efficient laser output it is, therefore, necessary to clear the discharge region of these residuals before the next pulse arrives. From the geometry of the laser head it works out that at 3 atmos. litres/min flow rate the discharge region is cleared and replenished with fresh gas 21 times per second and 42 times at 6 6 atmos.litres/min flow rate. The experimentally observed optimum power output is around 22 Hz and 40 Hz at 3 litres/min and 6 litres/min respectively and supports the requirement of replenishment with fresh gas for the next pulsing of the discharge.

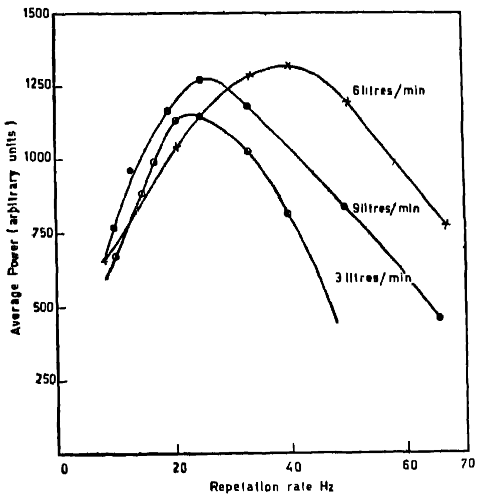


**Figure 4.** Variation of laser power with pulse repetition rate.

However, the experimentally observed optimum out put around 26 Hz repetition rate at 9 litres/min flow rate contradicts the expected rate of 63 Hz. But at this flow rate the discharge was unstable with lot of arcing in localised regions of the electrodes. It is not possible to account for this arcing as due to the presence of residual ions. The plausible explanation could be the thermal effects (Wasserstrom *et al* 1978). In our laser channel the dimensions of the gas chamber are small and this could lead to pressure gradient in the discharge region at high flow rates. This will lead to a local uneven heating which will reduce the gas density and increase the electron temperature, density and electrical conductivity. This increases the local current density and so also the ohmic heating rasing the temperature even further and leads to instability. Also, the brass electrode used in our system may have got pitted due to previous arcing and may also be contributing towards localised instability and arcing. The behaviour of the laser at high flow rates indicates that it is necessary to study the flow pattern of the gas and its relation with the discharge plasma if one desires to adopt the present design of transverse flow for very high repetition rates.

The laser has been used to pump some dyes to 'amplified spontaneous emission'. It has been used successfully to trigger spark gaps. When the beam was focussed on metal plates with a spherical quartz lense sparks were clearly visible (Bergmann 1976).

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